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ORIGINAL RESEARCH

COMPARISON OF RANGE OF MOTION, STRENGTH, AND HOP TEST PERFORMANCE OF DANCERS WITH AND WITHOUT A CLINICAL DIAGNOSIS OF FEMOROACETABULAR IMPINGEMENT

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ABSTRACT

Background: Dancers commonly experience anterior hip pain caused by femoroacetabular impingement (FAI) that interrupts training and performance in dance. A paucity of literature exists to guide appropriate evaluation and management of FAI among dancers.

Purpose: The purpose of this study was to determine if dancers with clinical signs of FAI have differences in hip range of motion, strength, and hop test performance compared to healthy dancers.

Study Design: Quasi-experimental, cohort comparison.

Methods: Fifteen dancers aged between 18- 21 years with clinical signs of FAI that included anterior hip pain and provocative impingement tests were compared to 13 age-matched dancers for passive hip joint range of motion, isometric hip strength, and performance of the medial triple hop, lateral triple hop, and cross-over hop tests.

Results: No statistically significant differences in range of motion were noted for flexion (Healthy = 145° ± 7°; FAI = 147° ± 10°; p = 0.59), internal rotation (Healthy = 63° ± 7°; FAI = 61° ± 11°; p = 0.50), and external rotation (Healthy = 37° ± 9°; FAI = 34° ± 12°; p = 0.68) between the two groups. Hip extension strength was significantly less in the dancers with FAI (224 ± 55 Newtons) compared to the healthy group (293 ± 58 Newtons; F(1,26) = 10.2; p = 0.004). No statistically significant differences were noted for flexion, internal rotation, external rotation, abduction, or adduction isometric strength. The medial triple hop test was significantly less in the FAI group (354 ± 43 cm) compared to the healthy group (410 ± 50 cm; F(1,26) = 10.3; p = 0.004). Similar results were observed for the lateral hop test, as the FAI group (294 ± 38 cm) performed worse than the healthy controls (344 ± 54cm; F(1,26) = 7.8; p = 0.01). There was no statistically significant difference between the FAI group (2.7 ± 0.92 seconds) and the healthy group (2.5 ± 0.75 seconds) on the crossover hop test.

Conclusion: Dancers with FAI have less strength of the hip extensors and perform worse during medial and lateral hop triple tests compared to healthy dancers. Clinicians may use this information to assist in screening of dancers with complaints of hip pain and to measure their progress for return to dance.

Level of Evidence: 3B, non-consectutive cohort study

Key words: Dancers, femoroacetabular impingement, functional performance, hop test.

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INTRODUCTION

The hip region is the second most commonly injured area of the body among dancers,[1] The injury rate for the hip joint in dancers is 0.77 injuries per 1000 hours of dance.[1] Dancers with pain in the hip region often describe the symptoms in the proximal, anterior aspect of the thigh and groin region.[2] Femoroacetabular impingement (FAI) is a common cause of anterior hip pain in dancers. FAI occurs as the femoral head/neck region contacts the acetabular margin resulting in potentially damaging stresses to the capsule, synovium and labrum of the hip joint. In the general population, FAI is often associated with abnormal proximal hip morphology.[3] Although dancers experience symptoms of FAI more frequently than non-dancers, abnormal hip morphology has not been found to be a common cause of FAI in this population. In dancers, FAI has been attributed to the extremes of range of motion required for common dance maneuvers,[4] an inability to adequately handle the muscular demands of dance,[5] and a rigorous training schedule.[6] Despite the prevalence of anterior hip pain among dancers, a paucity in the literature exists to establish appropriate parameters in the evaluation and management of FAI among dancers.

Screening procedures to identify risk factors associated with musculoskeletal injury to the spine and lower extremities of dancers have been utilized by sports medicine clinicians.[1] These musculoskeletal screens include assessments of range of motion, flexibility, and strength. Although existing screening procedures may help identify risk characteristics for potential injury, none of these procedures have been shown to aid in the detection of intra-articular hip pathology, specifically FAI. Furthermore, none of the current screens have included a dynamic assessment of the dancer's ability to leap and land. Leaping and landing is an important component of many dance disciplines and is repetitively performed during dance performance and training.[7] Thus, an ideal screening tool for dancers may include functional tests that assess the dancer's leaping and landing abilities.[2] Recently, researchers have shown good reliability of hop tests including the medial triple hop, lateral triple hop, and cross-over hop tests performed on dancers with non-specific hip pain.[2] The distance traveled during the medial triple hop test was shown to be significantly less in the symptomatic limb of subjects with non-specific hip pain compared to the non-symptomatic limb.[2] Further study is warranted to investigate if these hop tests are useful measures to be included in screening for symptoms related to femoracetabular impingement as well as during assessment of athletes to determine the readiness to return to dance activities. Determining how dancers with clinical signs of FAI perform on hop tests compared to healthy, non-symptomatic dancers may be an important step toward developing functionally specific screening measures for preventing and managing the symptoms associated with FAI in dancers. The purpose of this study was to determine if dancers with clinical signs of FAI have differences in hip range of motion, strength, and hop test performance compared to healthy dancers. The hypotheses were that healthy dancers would demonstrate greater muscular strength, less range of motion, and significantly greater performance on each respective hop test compared to the dancers with FAI. The information gained from this study may help to define tests and measures to screen for FAI and establish baseline values to help determine when a dancer may be appropriate to return to dance activity.

METHODS:

Subject Recruitment

Female dancers between the ages of 18–22 years who were enrolled in a collegiate performing arts program and participating in a minimum of eight hours of dance training in ballet, jazz, tap, lyrical, or modern dance disciplines were recruited for this research study. All participants read and consented to participate in this IRB approved study. Dancers that volunteered to participate in the study were categorized into either an FAI group or a healthy dancer group based on the combination of subjective complaints and physical exam. Inclusion criteria for the FAI group were: a subjective report of groin pain and provocation of familiar symptoms with the anterior impingement test (combination of flexion, adduction, and internal rotation of the hip joint) and the FABER (combination of the flexion, abduction and external rotation) test. The dancers categorized in the healthy dancer group were enrolled in the same

collegiate dance program without any complaints of lumbar or lower extremity pain including anterior hip pain, and who presented with negative anterior impingement and FABER tests. These criteria were selected based on previous research that reported excellent sensitivity (0.97) for the combination of an absence of groin pain and negative findings with the anterior impingement and FABER tests for ruling out FAI.[8]

Data Collection

Height, weight, age, a visual numeric pain rating scale (0-10) of the hip region during dance activity, and self-reported functional rating for the hip joint (Hip Outcome Score Activities of Daily Living and Sports Scales) were collected to describe and compare the sample populations. The subject's hip range of motion and strength was measured followed by performance of the medial triple, lateral triple, and cross-over hop tests. All data collection was performed by the primary investigator (BRK) who has 15 years experience as an outpatient physical therapist with advanced certification in Sports and Orthopedic Physical Therapy.

Range of Motion

Passive range of motion of the hip joint for flexion, external rotation, and internal rotation was performed as described by Holm et al.[9] The range of motion measures employed in this study have shown good intra-rater reliability (ICC = 0.82-0.90).[9] Internal and external rotation range of motion was assessed with the subject prone with their knees flexed to 90 degrees. An angle formed by an imaginary vertical line and the shaft of the tibia was quantified with a standard goniometer (Baseline Standard 12-inch goniometer, Fabrication Enterprises, White Plains, NY) to determine internal and external rotation motion. Hip flexion was measured in the supine position. With the knee joint in full flexion, the femur was moved towards the ipsilateral shoulder until an endpoint was noted without compensation from the pelvis. The hip flexion angle was determined by the angle formed between the bisection of the trunk and an imaginary line connecting the greater trochanter to the lateral femoral epicondyle. All range of motion measures were repeated three times and averaged for data analysis. The order in which range of motion measures were taken was randomized.

Isometric Hip Strength

Next, isometric muscle testing of the hip was performed. Muscle testing was performed with a handheld dynamometer (Microfet 3, Hoggan Medical Industries, West Jordan, UT) for strength of hip flexion, extension, abduction, adduction, internal rotation, and external rotation.[10,11] The dynamometer was placed just proximal to the malleoli for each respective motion as the subject applied maximal force into the pad of the dynanometer. The order in which strength measures were taken was randomized. Hip internal rotation, external rotation, and extension were performed with the subject in a prone position with the non-testing hand of the examiner stabilizing the pelvis. Hip adduction was performed in sidelying on the ipsilateral limb and the opposite limb supported. Hip abduction was performed from sidelying on the contra-lateral limb and the examiners non-testing hand stabilizing the pelvis. Hip flexion was performed with the patient in a supine position, with the knee fully extended. Intra-rater reliability has been previously reported as good for muscle testing in these positions (ICC = 0.77 – 0.97).[10,11] Three trials of muscle tests were performed with a rest time of 30 seconds between trials. The average of three trials for each direction was used for data analysis.

Hop Testing

The subjects then completed the medial triple hop test, lateral triple hop test, and cross-over hop test in random order as previously described by Kivlan et al.[2] To perform the medial triple hop test, the subject stood on the designated limb and was asked to perform three consecutive hops in the medial direction (Figure 1). The total distance traveled was recorded. The lateral triple hop test was performed in similar fashion, only the subject hopped in a lateral direction (Figure 2). The crossover hop test measures the time required to hop on a single limb six meters across a line 15cm in width. The subject must clear the 15cm line with each subsequent hop as they hop in diagonal fashion as fast as possible to the end of the line (Figure 3). Each subject performed six trials for each hop test with a 30-second rest between tri-

Figure 1. *The subject hops medially for three consecutive hops to perform the medial triple hop test. The total distance traveled is measured in centimeters. The average of 3 trials was used for data analysis.*

Figure 2. *The subject hops laterally for three consecutive hops to perform the lateral triple hop test.The total distance traveled is measured in centimeters. The average of 3 trials was used for data analysis.*

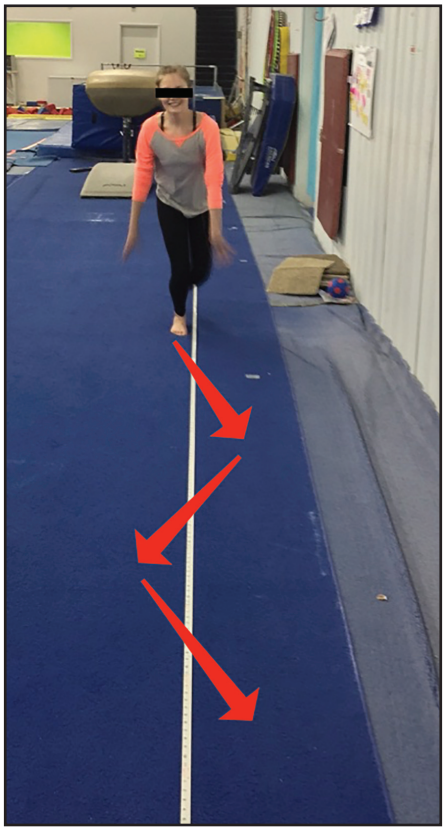

Figure 3. *The subject performs the cross-over hop test by hopping as fast as possible on the involved limb diagonally over the entire distance of a 6-meter line. The total time required to hop to the end of the line is recorded in seconds.*

als to minimize the effects of fatigue during repeated trials of hop testing. The average of the final three trials was used for data analysis. The hop tests used in this study have been previously studied on dancers with hip pain and have demonstrated excellent test-retest reliability (ICC = 0.89-0.96).[2]

Statistical Methods

All data were entered into a commercially available statistical software program (SPSS 21.0; Chicago, IL) for data analysis. Descriptive statistics were computed and compared with a multivariate analysis of variance to describe subject characteristics with regard to height, weight, pain rating, and self-reported function for each group. A multivariate analysis of variance compared functional performance measures that included range of motion, strength, and hop performance between the FAI group and the healthy group of dancers, with an a priori alpha set at 0.05.

Table 1. *The characteristics of the subjects in the FAI group versus the healthy dancers. (Reported as Mean + Standard Deviation)*

	Healthy (n=13)	FAI (n= 15)
Age (years)	18.9 ± 1.3	19.6 ± 1.4
Height (cm)	166.6 ± 1.4	164.9 ± 6.9
Weight (kg)	65.8 ± 6.2	59.0 ± 8.4
Pain (0-10)	0.8 ± 1.9	2.6 ± 1.6
Hip Outcome Score ADL subscale (0-100%)	94.4 ± 6.4*	85.8 ± 9.4*
Hip Outcome Score Sports subscale (0-100%)	94.8 ± 7.7*	81.1 ± 15.8*

FAI= Femoroacetabular impingement, *=Significant difference between groups ($p<0.05$)

RESULTS

Subject Characteristics

There were 15 dancers that volunteered for the study that met the inclusion criteria for the FAI group and an additional 13 dancers that volunteered to be part of the healthy control group. Table 1 displays the characteristics of the subjects in the FAI group versus the healthy dancers. There were no statistical differences between the groups with regards to height, weight, or age ($p>0.05$). There was a significant difference in self-reported pain and function between the groups. The FAI group had lower daily function and sports function as per the Hip Outcome Score Activities of Daily Living and Sports scales and greater pain during dance compared to the healthy dancers.

Functional Performance Measures

The results of the multivariate analysis of variance revealed that there was a statistically significant difference in functional performance measures among dancers with FAI versus healthy dancers. ($F(12,15) = 2.71$, $p=0.036$; Wilks Lambda = 0.32, partial $\eta^2 = 0.68$)

Table 2. *Ranges of motion values for the hip joint of the healthy dancers and the dancers with FAI. (Reported as Mean + Standard Deviation)*

	Range of Motion (Degrees)	
	Healthy (n=13)	FAI (n= 15)
Flexion	145±7°	147±10°
External Rotation	63±7°	61±11°
Internal Rotation	37±9°	34±12°

FAI= Femoroacetabular impingement

Range of Motion

Table 2 displays the ranges of motion values for the hip joint of the healthy dancers and the dancers with FAI. The univariate analysis revealed that there were no statistically significant differences in range of motion values for flexion (Healthy = 145° ± 7°; FAI = 147° ± 10°; $p=0.59$), internal rotation (Healthy = 63° ± 7°; FAI = 61° ± 11°; $p=0.50$), or external rotation (Healthy = 37° ± 9°; FAI = 34° ± 12°; $p=0.68$) between the two groups.

Strength

Table 3 displays the strength values of the hip joint for the healthy dancers versus the dancers with FAI. Hip extension strength was significantly less in the dancers with FAI (224 ± 55 Newtons) compared to the healthy group (293 ± 58 Newtons; $F(1,26) = 10.2$; $p=0.004$). There was no statistically significant difference between the FAI group and the healthy group in strength values for hip flexion, internal rotation, external rotation, abduction, or adduction.

Hop Tests

Table 4 displays the hop test performances of the healthy dancers versus dancers with FAI. The

Table 3. *Isometric strength values of the hip joint for the healthy dancers versus the dancers with FAI. (Reported as Mean + Standard Deviation)*

	Force (Newtons)	
	Healthy (n=13)	FAI (n= 15)
Flexion	214±42N	196±29N
Extension	293±58N*	224±55*
Abduction	134±42N	122±24N
Adduction	121±48N	115±34N
External Rotation	99±26N	89±21N
Internal Rotation	87±26N	73±22N

FAI= Femoroacetabular impingement, N=Newtons, *= statistically significantly different at $p<0.05$

Table 4. *Hop test performances of the healthy dancers versus dancers with FAI. (Reported as Mean + Standard Deviation)*

	Hop Test Performance	
	Healthy (n=13)	FAI (n= 15)
Medial triple hop	410±50cm*	354±43cm*
Lateral triple hop	343±54cm*	394±38cm*
Cross-over hop	2.5sec±0.7cm*	2.7sec±0.9cm*

FAI= Femoroacetabular impingement,cm= centimeters, sec= seconds, *= statistically significantly different at $p<0.05$

medial triple hop test was significantly less in the FAI group (354 ± 43cm) compared to the healthy group (410 ± 50cm; F(1,26) = 10.3; p = 0.004). Similar differences were seen for the lateral hop test, as the FAI group (294 ± 38cm) performed worse than the healthy controls (344 ± 54cm; F(1,26) = 7.8; p = 0.01). There was no statistically significant difference between the FAI group (2.7 ± 0.92 seconds) and the healthy group (2.5 ± 0.75 seconds) for the crossover hop test (F(1,26) = 0.212; p = 0.65).

DISCUSSION

The purpose of this research project was to determine if dancers presenting with clinical signs of FAI have different patterns of hip range of motion and strength and perform differently with functional performance tests when compared to healthy, non-symptomatic dancers. It was hypothesized that healthy dancers would demonstrate greater muscular strength, less range of motion, and significantly greater performance on each respective hop test compared to the dancers with FAI. The original hypotheses proved to be only partially upheld.

Range of motion of the hip joint was not significantly different among the group of dancers with FAI versus the group without symptomatic FAI. This finding differs from what has been previously reported in studies of non-dancer populations with FAI. In non-dancer populations, a relative loss of hip flexion and internal rotation is commonly associated with FAI.[12] There were no observed differences in the FAI group versus the healthy group with regards to hip range of motion values. However, our results did show that both dancer groups had relative increased values for external rotation and less internal rotation range of motion at the hip joint, regardless whether they had symptomatic FAI or not. Previous work suggests dancers exhibit a relative increased external rotation and decreased internal rotation range of motion compared to healthy age-matched controls.[13] The results of the current study suggest that range of motion of the hip joint would have limited value as a screening measure to differentiate a dancer that has FAI from a healthy dancer. This is consistent with the findings of Gamboa et al.[1] that showed that hip range of motion measures were not risk factors of lower extremity injury in dancers. However, considering the demands of hip joint motion required during common dance maneuvers, range of motion measures of the hip joint may still be valuable to identify abnormal values from those established in the current study that may suggest hypomobility or hypermobility of the hip joint specific to the needs of a dancer.

It was also hypothesized that dancers with FAI would have diminished strength of the hip musculature. Previous research has shown decreased average cumulative strength of the hip flexors, extensors, internal rotators, external rotators, adductors, and abductors, as well as the knee flexors and extensors to be a common characteristic of injured dancers.[1] Subjects with FAI have been previously shown to have hip strength deficits of 28% for adduction, 26% for flexion, 18% for external rotation, and 11% for hip abduction.[14] The results of the current study showed that hip extension was the only direction that demonstrated a significant deficit of hip strength. A 24% deficit of hip extension strength was observed among the dancers with FAI compared to healthy dancers. Diamond et al[15] reported a 23% deficit in hip extension strength among active adults with symptomatic FAI versus healthy controls, but the study was not sufficiently powered. Contrary to the original hypothesis, hip abduction and rotation strength was not significantly less in the group of dancers with symptomatic FAI compared to controls similar to what has been shown through previous investigations.[14,15] Collectively, these findings may be further evidence of the apparent differences of dancers with FAI versus a non-dancer population with FAI.

The deficits noted with hip extension strength among the dancers with FAI may help to further explain the deficits also noted on the medial and lateral triple hop tests. Compared to males, females produced higher knee extensor moments relative to hip extensor moments during landing tasks.[16] This relative reduction of hip extensor moment has been attributed to decreased strength of the hip extensors.[16] Based on these previous findings, one could hypothesize that weakness of the hip extensors observed in the FAI group could limit the efficiency of the subjects to absorb landing forces and may explain why the medial triple hop and lateral triple hop tests were significantly less in dancers with FAI versus healthy

dancers. The medial and lateral triple hop tests were approximately 410cm and 343cm, respectively, in the group of healthy dancers. Dancers with FAI hopped less far by approximately 50cm for the medial triple hop test and the lateral triple hop test. Clinicians may use this information to understand normal hop distances and distances that may be expected in dancers that have clinical signs of FAI. This could lead to further studies that establish minimal hop distances that may be used to help detect intra-articular hip disease and determine a safe return to dance activity.

The results of this study build on a previous investigation that compared performance of the medial triple hop, lateral triple hop, and crossover hop tests on the involved versus the uninvolved side among a group of dancers with complaints of unilateral hip pain.[2] Previous work showed an average deficit of 17.84cm between the symptomatic and non-symptomatic side during the medial hop test.[2] The results of the current study demonstrated a significant difference of approximately 50cm between the performances on the medial hop test by injured dancers when compared to healthy dancers. In the previous study, however, the lateral hop test did not demonstrate a significant side-to-side difference.[2] The current study demonstrated a significant difference that was similar to that of the medial triple hop test when comparing dancers with FAI to healthy, age-matched dancers. Therefore, the lateral triple hop test may also have value in screening for FAI in female dancers that was not demonstrated in the previous study when comparing the injured to uninjured sides. The crossover hop test, similar to the previous study, did not demonstrate a difference between symptomatic and nonsymptomatic groups. Therefore, one may conclude that the crossover hop test has limited utility discerning dancers with hip pathology, specifically FAI. It would appear that dancers are still able quickly change direction while hopping and accomplish the test without notably affecting performance despite apparent hip pathology. Based on these findings, repeated hops in a medial or lateral direction may best exhibit greater differences among injured and non-injured hips than a timed test that requires change of direction.

Screening measures for the hip joint are needed for dancers as articular cartilage lesions and labral tears are common.[17] Thirty-five percent of dancers that have evidence of an intra-articular lesion on magnetic resonance imaging of the hip joint do not report pain.[18] Dancers that report pain tend to exhibit a higher threshold and tolerance for pain compared to non-dancers.[19] Dancers also distinguish poorly between pain that is customary and related to dance performance and pain that is associated with a potential injury.[20] Thus, pain alone cannot be a reliable indicator for intra-articular hip pathology. The results of this study identify differences of strength and functional performance measures in dancers with FAI versus those without FAI. This information may help in the future study and development of screening measures to aide in the early detection of FAI. Further research is needed to see if deficits in hip extension strength and/or hop test performance are actual risk factors for developing intra-articular hip pathology in dancers.

Limitations

There are limitations to this study that deserve consideration when interpreting the results. First, the generalizability of the results should be applied to only highly trained dancers. The population studied in the current study included elite dancers with proficiency in multiple disciplines of dance who were participating in advanced dance training at the collegiate level. The dancers with FAI from this study did not demonstrate strength[14] and range of motion deficits[21] that have been commonly associated with a diagnosis of FAI in the general population. Further, non-dancers are often diagnosed with FAI based on radiological evidence of abnormal hip morphology. In dancers, FAI may occur in the absence of abnormal anatomical morphology of the hip joint,[4] thus radiographic evaluation may not be helpful in determining a diagnosis. Therefore a diagnosis FAI was based on subjective complaints and special clinical tests. Few physical examination tests have been studied adequately in unbiased population samples to direct clinical decision making without further study.[22] However, the most current research supports the inclusion criteria used in the current study as a subjective complaint of groin pain in combination with provocation of symptoms with the anterior impingement test and the FABER test has sensitivity of 0.97, making this specific combination of signs and tests excellent to rule out FAI.[8] One must also consider that the functional

testing procedures employed in this study may also have been influenced by fatigue. To minimize the impact of fatigue from repeated strength and functional testing, large rest:work ratios were adopted from previous studies that demonstrated excellent inter-rater reliability.[2,23] Finally, the objective findings of this study cannot be interpreted as having the ability to predict femoracetabular impingement. The results of this study, however, illustrate certain characteristics of strength, range of motion and functional performance that are common deficits in dancers with FAI. It is unknown if these characteristics precede the onset of the symptoms among the dancers. Therefore, it cannot be determined if the deficits of hip extension strength and medial and lateral triple hop test performance observed in the current study will predict an occurrence of symptoms related to FAI. The results do however demonstrate factors that may be included in a prospective study in order to help determine contributory factors for the development of FAI among dancers.

CONCLUSIONS

The results of this study provide evidence for the use of the medial triple hop and lateral triple hop tests in the assessment of dancers with suspected FAI. Clinicians may expect dancers with FAI to have less strength of the hip extensors and perform worse during medial and lateral hop tests on their symptomatic side compared to healthy dancers. There were no apparent differences in range of motion patterns between the dancers with FAI and the healthy dancers. Clinicians may use this information to assist in screening for dancers with complaints of hip pain and to measure their progress during assessment for return to dance.

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